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Effect of Sodium Chloride Levels on Sponge Doughs and Breads

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ABSTRACT

Decreasing the salt level from 2 to 1% in sponge bread doughs of hard red winter (HRW) and spring (HRS) wheat flours decreased dough clean-up times, mixing times, and proof times, and slightly impaired initial dough handling qualities. Decreasing the amount of salt increased loaf volumes of breads made from HRS flours, but not those of HRW flours. Flavor scores of one-day-old breads made from optimally formulated HRS flour doughs with 1 and 2% salt were not significantly different from one another when compared to salt-free breads, which were rated significantly lower. One-day-old 1% salt breads were rated significantly lower when compared to 1.5 and 2% salt breads; differences were small and may be of limited importance. Flavor differences among three-day-old breads were not significant. Salt levels did not have a significant effect on texture scores for both one- and three-day-old breads. Flavor and texture scores of 1, 1.5, and 2% salt flour breads from two lots of HRW flour stored for one or three days were not significantly different.

Concern over the role of sodium chloride in the etiology of hypertension and/or high blood pressure has prompted the USDA to initiate research on the effect of salt on the functional and sensory properties of meats, cheeses, and dairy products. As many as 20% of white Americans older than 50 years and up to 40% of black Americans may have high blood pressure (1). Too much salt in the diet can contribute to hypertension. In many studies of various ethnic populations, a positive correlation exists between the average salt consumption and incidence of hypertension (2).

Grain and cereal products contribute up to 29% of an individual's total daily sodium intake, which is estimated to be 7.9 g, equivalent to 17.3 g of salt (3). Because wheat flours do not contain much sodium, most of this is contributed by added salt, leavening acids, and sodium bicarbonate. Three slices of bread contribute approximately 1 g of salt, which is equivalent to 12% of the recommended intake of 3.2 g of sodium per day. Adding 2% NaCl to bread contributes 88% of added sodium in a formula containing 2% skim milk solids and 0.5% each of yeast food and sodium stearoyl-2-lactylate. Thus, reducing the NaCl content by one-half yields a bread with 56% of the sodium of a bread with 2% NaCl. Because of this and because many people consume more than three slices of bread per day, we investigated the effect lowering salt levels has on the functional and organoleptic properties of white breads. For this purpose, both HRW and HRS wheat flours were used for sponge bread baking.

Adding up to 2% salt increases both the extensibility and resistance to extension of strong Canadian wheat flours and weak English flour doughs, as measured by the extensigraph (4). Adding up to 3% salt decreases the farinograph consistency of flour water doughs and increases both the resistance of the dough to extension and its extensibility (5). Adding up to 2 and 2.5% salt also increases peak viscosity of wheat starch suspensions in the Brabender amylograph (6,7). Additional farinograph experiments using nonfat dry milk (NFDM), as well as experiments with complete sponges and doughs, were done for this study.

All levels of salt markedly suppress yeast activity and increase proof times 10–20% for bread containing the normal 1.5–2% salt level (8). Salt has a tightening effect on gluten, making the doughs more machineable (3,9). This study describes further investigation of the effects of varying the dough absorptions and mixing times on the functional and baking properties of doughs. Varying yeast and salt levels, and the effect of salt level on shocking of doughs and compressions of their breads were also investigated. The hedonic ratings of breads of partially reduced salt content were also investigated, because no published studies were available.

MATERIALS AND METHODS

Materials

Two lots of bromated, enriched, bleached, and malted commercial HRS wheat flour were used. Lot I had 13.8% protein ($N \times 5.7$) and 0.40% ash; Lot II had 12% protein and 0.46% ash. One lot of enriched and bleached commercial HRW wheat flour had 10.8% protein and 0.49% ash. The second lot, also malted, had 11.7% protein and 0.47% ash.

Vacuum-packed Saf brand instant dry yeast, all-purpose vegetable shortening from Archer Daniels Midland Co., and Valley brand high-heat NFDM solids, of 1.7 mg soluble whey protein nitrogen (WPN)/g, finely granulated sugar, Sterling brand evaporated baker's-grade salt, and Patco Emplex brand sodium stearoyl-2-lactylate (SSL), were used. Malted barley flour used with HRW flour assayed 181° Lintner. Yeast food was made by blending 40% flour, 25% NaCl, 25% $CaSO_4$, 9.7% NH_4Cl, and 0.3% $KBrO_3$ for use with the HRW flour. With the exception of the $KBrO_3$, which was ground with a mortar and pestle, all of the ingredients were sifted through a 20-mesh screen before blending.

Baking Methods

The standard bake formula for both HRS and HRW flours is shown in Table I. Instant yeast was dry blended with the sponge ingredients before being mixed in an A-200 Hobart mixer. For panel studies, different yeast levels were used to

Table I. Bake Formula

Ingredient (%)	Sponge	Dough
Flour	65	35
Instant yeast		
HRS[a]	0.75	...
HRW[b]	1	...
Yeast food	0.5	...
Barley malt		
HRW[b]	0.2	...
Sugar		
HRS[a]	...	6
HRW[b]	...	7.5
Shortening	...	3
NFDM[c]	...	2
Salt	...	0–2
SSL[d]	...	0.5

[a]HRS = hard red spring wheat flour.
[b]HRW = hard red winter wheat flour.
[c]NFDM = nonfat dry milk.
[d]SSL = sodium stearoyl-2-lactylate.

Table II. Effect of Salt and Nonfat Dry Milk on the Farinograph Indices of Hard Red Spring Flour Lot I

		Minutes		
% Salt	% Absorption	*I*	*M*	*R*
0	62.1	2-¾	10	19
1	62.2	4-¾	13.5	24.5
1.5	62.3	5	13.5	28.5
2	62.3	5	17	32

Table III. Effect of Salt in the Complete Formula of Fermented Sponge and Mixed Dough on Farinograph Indices of Hard Red Spring Flour Lot I

		Minutes		
% Salt	% Absorption	*I*	*M*	*R*
0	58.7	3-¾	7	8
1	58.8	5	9-¼	12
2	59	6	11	18

[1]Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

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compensate for variable sugar levels, to maintain a relatively constant proof time with 2% salt doughs. 0.6% yeast was added to HRS flours with 4.5% sugar, and 0.9% yeast was added to flours with 7.5% sugar. Sponges were held for 3-½ hr at 30°C and 85% RH. Doughs were mixed to optimum development at the second speed (as judged by the author) and were given 25-min floor time at 30°C. After being divided into 525-g pieces, the doughs were rounded, and 12 min later, were sheeted and molded in a model 100 Moline molder, using constant settings for the sheeting rollers and pressure board. Doughs were proofed at 36°C to 1.6 cm above the top of the pan and baked at 213°C for 25 min. After cooling for 1 hr at room temperature, the bread was weighed and volumes were read by rapeseed displacement.

Bread Scoring

Breads were held overnight in a closed cabinet and scored the next day by the author. Crust color and grain were judged with mounted standards assigned numbers by the author. A light brown crust color rated 10 and a fine even grain received eight points. A uniform break with even vertical shredding along the top sides of the loaf was assigned four points; an even loaf shape, slightly rounded in the center, was assigned three points. A loaf with even crust, sides, and bottom color received three points. A soft, velvety, silky texture was given a score of 10, as was a creamy white crumb color. A loaf with lesser attributes was graded less by half points in the judgment of the scorer; 48 points was the maximum score.

Farinograph

Farinograph characteristics were determined in duplicate according to the 300-g constant flour weight AACC method, number 54-21 (10). When used, salt or NFDM solids were preblended with the flour before titration. Farinographs also were run on the sponge and dough (300 g total flour). Dry dough ingredients were preblended, a 3-½-hr fermented sponge was added, and the mixture was titrated with distilled water to center the curve on the 500-BU line.

Analytical

Flour moisture, ash, and protein ($N \times 5.7$) were determined using AACC methods 44-15A, 08-01, and 46-12, respectively (10). Undenatured whey protein nitrogen of NFDM solids was determined by AACC method 46-21. CO_2 production of doughs, expressed as millimeters of mercury (mm Hg) pressure, was measured by scaling 17.5 g of freshly mixed sponge and dough into a pressuremeter cup, sealing, and holding at 30°C for 97 min after first mixing (equivalent to the time a 60-min proofed dough is placed in the oven). Shock tests were done by dropping fully proofed doughs three times from 6.5 cm height immediately before baking. Bread pH was determined using AACC method 02-52. Compression of bread slices from duplicate loaves was determined by method 74-10, using a Baker compressimeter. The bread was cooled for 1 hr, sealed in 1.5-ml polyethylene bags, and stored at room temperature. Six center slices 1.2-cm thick were cut on an Oliver bread slicer immediately before testing.

Organoleptic Analyses

Bread made for hedonic studies was cooled for 1-½ hr out of the oven and stored in polyethylene bags at room temperature. Sliced breads of 1.2-cm thickness with the crusts removed were evaluated for both taste and texture on a nine-point hedonic scale (from 1, "dislike extremely," to 9, "like extremely") by a panel of 14 to 18 judges (11). The evaluations were done during the morning in closed booths in a light-controlled room. Although not experienced in evaluating breads, the judges had previous experience in taste panel evaluation of a variety of food products. Triangle tests, in which the panelists were asked to determine the odd sample when two were alike and one was different, were done separately. Saltiness tests also were done separately by evaluating bread on a seven-point intensity scale. A marking of zero was "not salty"; 1, "slightly salty"; 2, "moderately salty"; and 3, "very salty"; −1, "slightly lacking salt"; −2, "moderately lacking salt"; and −3, "definitely lacking salt."

Data for panels and significance of bake results were verified by analysis of variance and Duncan's multiple range test to determine significance of results. A fractional factorial design was also used with three variables of mixing time, percentage of water absorption, and percentage of salt level (12).

Table IV. General Linear Model for Hard Red Spring Flour Lot I Doughs and Bread[a]

	Probability > F			
Effects	Seconds Clean-Up Time	mm Hg Pressure	Minutes Proof Time	Specific Loaf Volume
Salt[b]	<0.01	<0.01	<0.01	<0.01
Absorption[c]	<0.01	>0.05	>0.05	>0.05
Salt × absorption[c]	<0.05	>0.05	>0.05	>0.05

[a] Minutes mixing time: 3, 3.75, and 4.5. Mixing time (MT), MT × salt, and absorption × MT all >0.05.
[b] Percentage of salt: 1, 1.5, and 2.
[c] Percentage of absorption: 60.5, 62, and 63.5.

Table V. Effect of Salt Level and Yeast Level on the Baking Quality of Hard Red Spring Flour Lot I (Doughs and Breads[a]) at 62% Absorption

Percentage of Salt[b]	Percentage of Instant Yeast	Initial Dough Handling	Seconds Clean-Up[c]	Minutes Proof Time[c]	mm Hg Pressure (17.5 g) (Dough)[c]	Specific Loaf Volume (cc/g)	Grain Score[c]
2	0.75	Excellent	15.3 c	60 a	161 a	5.63	7.1 a
1.5	0.75	Very good	12.7 bc	54.3 b	180 b	5.76	7 a
1.5	0.61	Very good	10.7 b	58.7 a	162 a	5.75	7.25 a
1	0.75	Good	7.7 b	46.7 c	209 c	5.79	6.67 b
1	0.47	Very good	10 b	60 a	158 a	5.73	7.3 a
0	0.75	Fair	0 a	42.7 d	227 d	5.8	6.5 b
Standard Deviation (4 loaves)			±2.3	±1.73	±3.86	±0.15	±0.27

[a] Bread scores = all not significant.
[b] Respective minutes mixing time: 4, 3-½, 3, and 2.
[c] Different letters in each column are significantly different ($P < 0.5$).

Table VI. Effect of Shock on Proofed Hard Red Spring Flour (Lot I) Doughs of Different Salt Levels on Specific Loaf Volume of Their Breads

Percentage of Salt	Specific Loaf Volume (cc/g) Control	Shocked[a]
0	5.93	5.7
1	5.78	5.87
2	5.53	5.43

Standard deviation = ±0.17 cc (duplicate loaves).

[a] Dropped three times from 6.5 cm height.

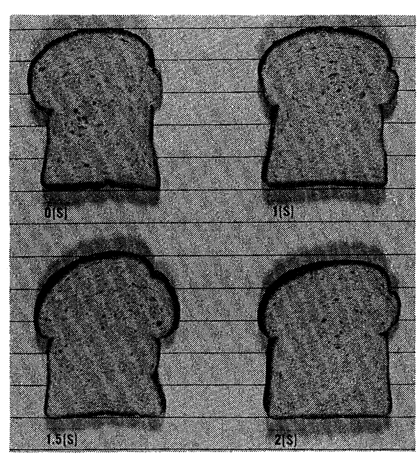

Fig. 1. Effect of salt level on appearances of center cut bread slices from hard red spring flour. Numbers = %; and (S) = salt.

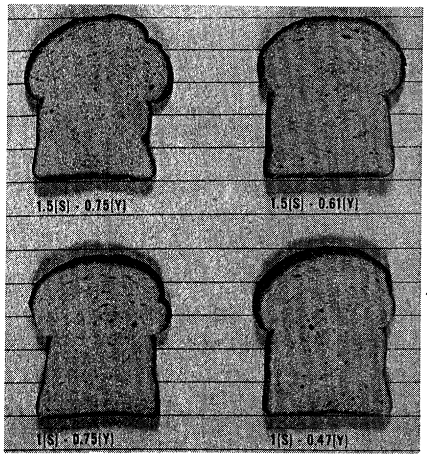

Fig. 2. Effect of salt and yeast levels on appearances of center cut bread slices from hard red spring flour. Numbers = %; (S) = salt; and (Y) = yeast.

RESULTS AND DISCUSSION

HRS Wheat Flour

Adding salt decreases farinograph

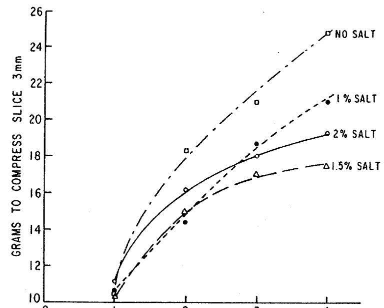

Fig. 3. Effect of salt level on the compression of slices from hard red spring flour.

Table VII. Effect of Salt and Yeast Levels on Differentiation of Hard Red Spring Flour (Lot I) Breads by Triangle Tests

Percentage of Salt	Number of Panelists	Number of Correct Choices	Significance of *P*
0 versus 2	18	17	<0.001
1 versus 2	18	13	0.001
1 versus 2	19	11	0.05
1.5 versus 2	19	11	0.05
1.5 (0.75 yeast) versus 1.5 (0.61 yeast)	12	4	Not significant
1 (0.75 yeast) versus 1 (0.47 yeast)	12	2	Not significant

consistency of wheat flour doughs (5), but adding salt to HRS flour plus 2% NFDM or to completely fermented sponges with dough ingredients did not significantly change farinograph absorption (Tables II and III). In these instances, adding salt significantly increased *I*, *M*, and *R* values. The water absorption value of flour, NFDM, and salt were close to that optimum absorption determined with this flour when optimum mixing times for each level of salt were used.

A fractional factorial design study showed that salt significantly affected clean-up times, mm Hg pressure of doughs, minutes of proof time, and specific loaf volumes (Table IV). Seconds of mixing to clean-up time and minutes of proof time increased as the amount of salt was increased; mm Hg pressure and specific loaf volumes decreased. Increasing absorption increased mixing time to clean-up. At low absorption, salt had no significant effect on mixing time to clean-up; at high absorption, it significantly increased mixing time to clean-up. Bread scores were not affected for the main effects studied. Dough handling was optimal at 62% absorption for all levels of salt. The pHs of breads were not significantly different, averaging 5.36–5.38.

The effects of three salt levels, as well as no salt, and different yeast levels on the baking quality of HRS flour Lot I bread and doughs at 62% absorption were studied (Table V). At the 0.75% yeast level, decreasing salt impaired the initial handling of doughs. Moderately more sticky handling and poorer sheeting dough out of the mixer was obtained, supporting the findings that decreasing salt decreases the extensibility of doughs (4,5). However, the handling of all doughs when sheeted in the molder was similar. Loaf volumes were not significantly affected at 62% absorption, although those of 2% salt breads were the lowest; however, grain scores decreased with decreasing salt. Reducing the yeast level of 1.5 and 1% salt doughs to 0.61 and 0.47%, respectively, increased both proof times and mm Hg pressure to equal that of the 2% salt doughs. Reducing the yeast level of 1% salt doughs to 0.47% improved their initial handling, giving a drier and better sheeting dough, and increased the fineness of their bread grains. The pHs of these breads were only approximately 0.05 higher than that of bread with 0.75% yeast. No simple explanation is apparent for the better handling of doughs with reduced yeast levels. Some of these findings are shown in the figures. Center slices of breads with 2% salt have slightly lower volumes than 0, 1, and 1.5% salt breads (Fig. 1). Increasing the salt level also produced a finer grain in the bread. Lowering the yeast level in 1.5 and 1% salt breads resulted in slightly finer grain and produced bread volumes comparable to those of their controls (Fig. 2).

Slices from up to four-day-old 1, 1.5, and 2% salt breads stored at room temperature have somewhat similar compressions, and after the first day are significantly softer ($P = <0.01$) than those of the salt-free breads (Fig. 3). 1% salt breads were slightly softer than 2% salt breads on the second day, equivalent on the third day, and significantly firmer ($P = <0.05$) on the fourth day. On the average, 1.5% salt breads were rated the softest of the breads at all storage times. These breads were made without SSL so that the inherent effect of salt level could be measured without having to add an antistaling compound.

The specific volumes of breads containing different salt levels were not significantly changed when their fully proofed doughs were shocked by being dropped three times from 6.5 cm height (Table VI). The data show that specific volumes of breads were increased ($P = <0.05$) when salt was decreased from 2 to 1 or 0%. These breads were also made without the stabilizing influence of SSL.

As shown in Table VII, panelists using triangle tests easily differentiated salt-free breads from 2% salt breads (17 correct choices out of 18). They could differentiate between 1.5 and 2% salt breads and 1 and 2% salt breads, but at a lower level of significance. The panelists could not differentiate between either 1 or 1.5% salt breads in which the levels of yeast had been reduced, respectively, from 0.75% to 0.47% and 0.61%.

The flavor ratings of 1 and 2% salt breads were equivalent, when compared to salt-free breads, even though the panelists differentiated between the two by using the triangle test (Table VIII). The data also show that the salt breads rated significantly higher than salt-free breads. Texture ratings were not significantly different.

On the other hand, statistical analyses of triplicate panels from 14 to 16 panelists by partitioning of squares showed that salt levels and storage times had significant effects on flavor scores. In these instances, 1, 1.5, and 2% salt breads were compared, using HRS flour II. The flavor scores of one-day-old 1% salt breads rated significantly, although not greatly, lower than either the 1-day-old 1.5 or 2% salt breads (Fig. 4.) Breads were made with different sugar levels because sugar may affect hedonic ratings. One-day-old breads with 7.5 and 6% sugar rated slightly, but not significantly, higher than those with 4.5% sugar. Flavor scores of three-day-old stored breads of all sugar and salt levels were similar, and they were significantly lower than those of the one-day-old breads. No significant texture differences were attributable to either salt or sugar levels, although breads with six and, especially, 7.5% sugar rated highest (Fig. 5). One- and three-day-old 1% salt breads with 6 or 7.5% sugar were rated as slightly lacking in salty flavor, whereas 2% salt breads of similar age and sugar level were rated as slightly salty (Table IX). The breads rated as having the best balance of salty to nonsalty flavor were those that contained 1.5% salt. Comparisons of ratings of 0, 1, and 2% salt breads made from HRS flour Lot II, as with HRS flour Lot I, showed that 1 and 2% salt breads had similar flavor scores (respectively, 6.65 versus 6.59 for one-day-old breads and 6.09 versus 6.45 for three-day-old breads) and rated significantly higher than salt-free breads, again showing that flavor score differences between two samples depend on the nature of the samples being compared. Texture ratings of the three breads were similar.

Table VIII. Effect of Salt Level on the Flavor and Hedonic Texture Scores of One-Day-Old Hard Red Spring Flour (Lot I) Breads[a]

Percentage of Salt	Flavor[b]	Texture
0	5.53 a	6.32
1	6.64 b	6.44
2	6.63 b	6.42

[a] Average of four loaves.
[b] Different letters are significantly different ($P = <0.01$).

Table IX. Effects of Salt and Sugar Levels and Age of Breads on Their Saltiness Scores[a]

Percentage of Salt	6% Sugar[b]		7.5% Sugar[b]	
	1 Day	3 Days	1 Day	3 Days
1	−0.70 a	−0.74 a	−0.70 a	−0.57 a
1.5	−0.23 ab	0 b	−0.17 b	0.06 b
2	0.44 b	0.94 c	0.56 c	0.75 c

[a] 1 = slightly salty; 0 = just right, and −1 = slightly lacking salt.
[b] Different letters in each column are significantly different at $P = <0.05$.

HRW Wheat Flour

With HRW flour (Table X), salt levels produced farinograph water absorption responses similar, in some instances, to those of HRS flour (Table II and III). Added salt decreased absorption of the flour by nearly 2% but did not change the absorption of completely fermented sponge with its dough ingredients. Although absorptions of 1–2% salt doughs with 2% NFDM were similar, they were slightly higher than that of the salt-free dough. As with HRS flour, salt increased arrival times, mixing times, and stability values (data not shown).

A fractional factorial designed study showed that salt very significantly affected seconds of mixing time to clean-up, mm Hg pressure, and minutes of proof time, but not specific loaf volume (Table XI). Changes with the affected indices were similar to those of HRS flour. Increasing absorption increased clean-up time, as with HRS flour, but also significantly increased mm Hg pressure and specific loaf volume. Increasing mixing time significantly increased proof time and specific loaf volume. At low absorption, increasing mixing time and salt significantly increased specific loaf volume; at high absorption, this significantly decreased specific loaf volume. At low absorption, increasing salt had no significant effect in clean-up times, but at high absorption, it significantly increased clean-up times. At low absorption, increasing salt increased proof times significantly more than it did at high absorption.

Table X. Percentage of Farinograph Absorption of Hard Red Winter Flour

Salt %	Flour + Salt	Flour + Salt + 2% Nonfat Dry Milk	Fermented Sponge and Dough
0	57.1	57.4	52.9
1	55.3	58	52.7
1.5	55.3	58.3	···
2	55.3	58.3	52.7

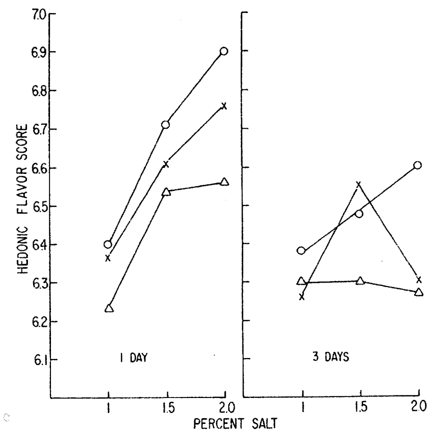

Fig. 4. Effect of salt and sugar levels on the hedonic flavor scores of hard red spring flour breads stored for one and three days. O = 7.5% sugar; X = 6% sugar; and △ = 4.5% sugar.

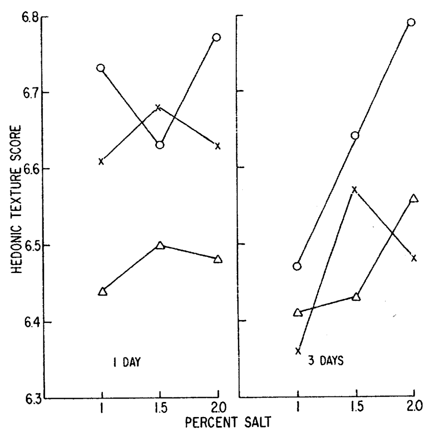

Fig. 5. Effect of salt and sugar levels on the hedonic texture scores of hard red spring flour breads stored for one and three days. O = 7.5% sugar; X = 6% sugar; and △ = 4.5% sugar.

Table XI. General Linear Method for Hard Red Winter Flour Doughs and Breads[a]

Effects	Probability > F: Seconds Clean-Up	mm Hg Pressure	Minutes Proof Time	Specific Loaf Volume
Salt[b]	<0.01	<0.01	<0.01	>0.05
Absorption[c]	<0.01	<0.05	>0.05	<0.01
Mixing time[d]	>0.05	>0.05	<0.05	<0.05
Salt × absorption	<0.05	>0.05	<0.01	<0.05

[a] Mixing time × absorption all not significant, except specific loaf volume, <0.01. Salt × MT not significant.
[b] Percentage of salt: 1, 1.5, and 2.
[c] Percentage of absorption: 57.5, 59, and 60.5.
[d] Minutes mixing time: 3.5, 4, and 4.5.

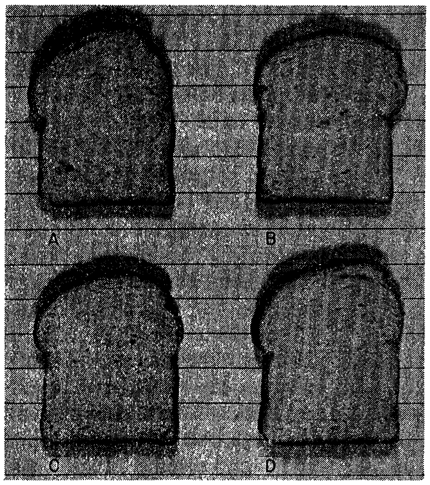

Fig. 6. Effect of salt level on the appearances of center cut bread slices for hard red spring flour. A = 0%; B = 1%; C = 1.5%; and D = 2% salt.

Grain and bread scores were unaffected for the main effects shown in Table XI. Dough handling was optimal at 59% absorption. As with HRS flours, reducing the salt from 2 to 1% produced a poorer sheeting and slightly stickier dough out of the mixer at optimum mix times: 3.5 min for 1% salt doughs, 4 min for 1.5% salt doughs, and 4.5 min for 2% salt doughs.

Grain, symmetry, and height of the center slices of breads with no salt or 1, 1.5, and 2% salt were similar (Fig. 6). Specific volumes of the cut loaves are much the same, ranging from 5.68 to 5.80 cc/g. Reducing the yeast level did not favorably affect the handling of doughs, as with HRS flour doughs, or affect the specific volume and appearance of the breads. Compressions of stored 1 and 2% salt breads were similar, except the three-day-old 1% salt breads were significantly firmer. Both salt breads were significantly softer than the salt-free stored breads. Shocking of proofed doughs also caused no significant change of volume in any of the breads.

Salt levels of 1–2% did not significantly affect the flavor and texture ratings of HRW flour breads containing 7.5% sugar that were evaluated when they were one and three days old (Table XII). Analyses were made in duplicate. Flavor ratings of breads made from this flour were lower

Table XII. Effect of Salt Levels on the Flavor and Texture Hedonic Scores of Hard Red Winter Flour Breads[a]

Percentage of Salt	1-Day-Old Flavor	1-Day-Old Texture	3-Day-Old Flavor	3-Day-Old Texture
1	5.92	6.52	5.52	6.13
1.5	6.04	6.59	5.66	6.24
2	5.83	6.52	5.15	6.10

[a] Column differences all not significant.

than those given one-day-old salt breads with HRS flour (Table IX), but texture scores were similar.

Using a second lot of HRW flour containing 11.6% protein, flavor ratings of 6.30 for one-day-old 2% salt bread and 6.65 for 1% salt bread were obtained. Ratings of 5.67 and 5.84, respectively, for three-day-old bread were obtained. Some staleness occurred in three-day-old HRW flour breads of both lots, which may have contributed to their lowered hedonic ratings. The flavor ratings of 1% salt breads made from HRW flours were as high or higher than those of the 2% salt breads. This may be due to the gradual acceptance of the panel to bread of lower salt content (the studies with HRW flour were the last to be made). This view is supported by a previous report (13).

CONCLUSION

Studies with both HRS flour containing 13.8 and 12 protein and HRW flour containing 10.8% and 11.7% protein showed that reducing salt content from the normal 2% to 1% decreased mixing times, mixing time to clean-up, and proof times of doughs. Yeast activity also increased and optimum dough development was slightly impaired. Optimum bake absorption, the effect of shocking of fully proofed doughs on bread volume, compressions, and total scores of breads were not significantly affected. Lowering the yeast level in 1% salt doughs by 36–38% increased proof times of these doughs to equal those of 2% salt doughs and produced very acceptable breads. Lowering the yeast level using HRS flour produced a better handling dough.

Compared to salt-free doughs, 1 and 2% salt HRS flour doughs handled much better; the flavor of their breads was highly rated by the panel. However, comparison of the flavor of 1, 1.5, and 2% salt breads at 4.5, 6, or 7.5% sugar showed that one-day-old 1% salt breads were rated significantly lower than the other two. These differences in score were relatively small; the averages rated above "like slightly" on the nine-point hedonic score. Additional data from a larger panel could help prove that these small differences are real. Salt did not significantly affect the flavor ratings of these three-day-old breads. In contrast, one-day-old HRW flour breads with 1, 1.5, and 2% salt were not significantly different. Using 1% salt in place of 2% salt shortened processing times of doughs and bread from both types of flour and produced acceptable breads with only slight impairment of initial dough handling and possible loss of flavor but not objective or subjective texture quality. 1.5% salt only very slightly impaired initial dough handling and its breads were fully as acceptable as those with 2% salt.

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Slices from up to four-day-old 1, 1.5, and 2% salt breads stored at room temperature have somewhat similar compressions, and after the first day are significantly softer ($P = <0.01$) than those of the salt-free breads (Fig. 3). 1% salt breads were slightly softer than 2% salt breads on the second day, equivalent on the third day, and significantly firmer ($P = <0.05$) on the fourth day. On the average, 1.5% salt breads were rated the softest of the breads at all storage times. These breads were made without SSL so that the inherent effect of salt level could be measured without having to add an antistaling compound.

The specific volumes of breads containing different salt levels were not significantly changed when their fully proofed doughs were shocked by being dropped three times from 6.5 cm height (Table VI). The data show that specific volumes of breads were increased ($P = <0.05$) when salt was decreased from 2 to 1 or 0%. These breads were also made without the stabilizing influence of SSL.

As shown in Table VII, panelists using triangle tests easily differentiated salt-free breads from 2% salt breads (17 correct choices out of 18). They could differentiate between 1.5 and 2% salt breads and 1 and 2% salt breads, but at a lower level of significance. The panelists could not differentiate between either 1 or 1.5% salt breads in which the levels of yeast had been reduced, respectively, from 0.75% to 0.47% and 0.61%.

The flavor ratings of 1 and 2% salt breads were equivalent, when compared to salt-free breads, even though the panelists differentiated between the two by using the triangle test (Table VIII). The data also show that the salt breads rated significantly higher than salt-free breads. Texture ratings were not significantly different.

On the other hand, statistical analyses of triplicate panels from 14 to 16 panelists by partitioning of squares showed that salt levels and storage times had significant effects on flavor scores. In these instances, 1, 1.5, and 2% salt breads were compared, using HRS flour II. The flavor scores of one-day-old 1% salt breads rated significantly, although not greatly, lower than either the 1-day-old 1.5 or 2% salt breads (Fig. 4.) Breads were made with different sugar levels because sugar may affect hedonic ratings. One-day-old breads with 7.5 and 6% sugar rated slightly, but not significantly, higher than those with 4.5% sugar. Flavor scores of three-day-old stored breads of all sugar and salt levels were similar, and they were significantly lower than those of the one-day-old breads. No significant texture differences were attributable to either salt or sugar levels, although breads with six and, especially, 7.5% sugar rated highest (Fig. 5). One- and three-day-old 1% salt breads with 6 or 7.5% sugar were rated as slightly lacking in salty flavor, whereas 2% salt breads of similar age and sugar level were rated as slightly salty (Table IX). The breads rated as having the best balance of salty to nonsalty flavor were those that contained 1.5% salt. Comparisons of ratings of 0, 1, and 2% salt breads made from HRS flour Lot II, as with HRS flour Lot I, showed that 1 and 2% salt breads had similar flavor scores (respectively, 6.65 versus 6.59 for one-day-old breads and 6.09 versus 6.45 for three-day-old breads) and rated significantly higher than salt-free breads, again showing that flavor score differences between two samples depend on the nature of the samples being compared. Texture ratings of the three breads were similar.

Table VIII. Effect of Salt Level on the Flavor and Hedonic Texture Scores of One-Day-Old Hard Red Spring Flour (Lot I) Breads[a]

Percentage of Salt	Flavor[b]	Texture
0	5.53 a	6.32
1	6.64 b	6.44
2	6.63 b	6.42

[a] Average of four loaves.
[b] Different letters are significantly different ($P = <0.01$).

Table IX. Effects of Salt and Sugar Levels and Age of Breads on Their Saltiness Scores[a]

Percentage of Salt	6% Sugar[b] 1 Day	6% Sugar[b] 3 Days	7.5% Sugar[b] 1 Day	7.5% Sugar[b] 3 Days
1	−0.70 a	−0.74 a	−0.70 a	−0.57 a
1.5	−0.23 ab	0 b	−0.17 b	0.06 b
2	0.44 b	0.94 c	0.56 c	0.75 c

[a] 1 = slightly salty; 0 = just right, and −1 = slightly lacking salt.
[b] Different letters in each column are significantly different at $P = <0.05$.

HRW Wheat Flour

With HRW flour (Table X), salt levels produced farinograph water absorption responses similar, in some instances, to those of HRS flour (Table II and III). Added salt decreased absorption of the flour by nearly 2% but did not change the absorption of completely fermented sponge with its dough ingredients. Although absorptions of 1–2% salt doughs with 2% NFDM were similar, they were slightly higher than that of the salt-free dough. As with HRS flour, salt increased arrival times, mixing times, and stability values (data not shown).

A fractional factorial designed study showed that salt very significantly affected seconds of mixing time to clean-up, mm Hg pressure, and minutes of proof time, but not specific loaf volume (Table XI). Changes with the affected indices were similar to those of HRS flour. Increasing absorption increased clean-up time, as with HRS flour, but also significantly increased mm Hg pressure and specific loaf volume. Increasing mixing time significantly increased proof time and specific loaf volume. At low absorption, increasing mixing time and salt significantly increased specific loaf volume; at high absorption, this significantly decreased specific loaf volume. At low absorption, increasing salt had no significant effect in clean-up times, but at high absorption, it significantly increased clean-up times. At low absorption, increasing salt increased proof times significantly more than it did at high absorption.

Table X. Percentage of Farinograph Absorption of Hard Red Winter Flour

Salt %	Flour + Salt	Flour + Salt + 2% Nonfat Dry Milk	Fermented Sponge and Dough
0	57.1	57.4	52.9
1	55.3	58	52.7
1.5	55.3	58.3	···
2	55.3	58.3	52.7

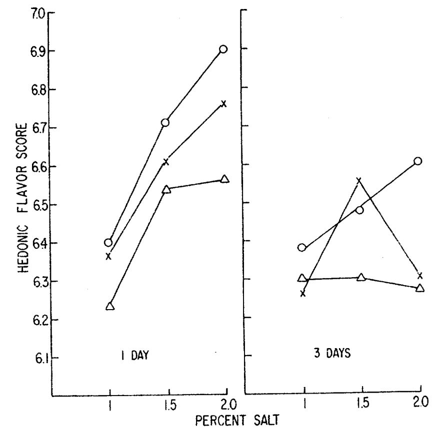

Fig. 4. Effect of salt and sugar levels on the hedonic flavor scores of hard red spring flour breads stored for one and three days. O = 7.5% sugar; X = 6% sugar; and △ = 4.5% sugar.

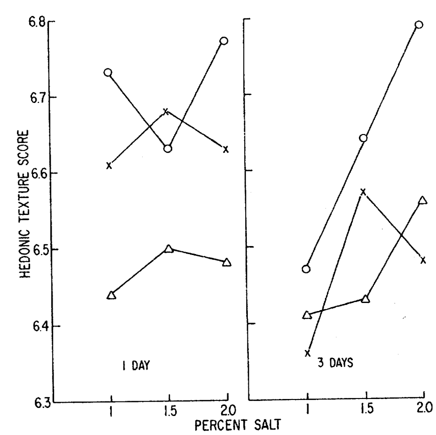

Fig. 5. Effect of salt and sugar levels on the hedonic texture scores of hard red spring flour breads stored for one and three days. O = 7.5% sugar; X = 6% sugar; and △ = 4.5% sugar.

Table XI. General Linear Method for Hard Red Winter Flour Doughs and Breads[a]

Effects	Probability > F Seconds Clean-Up	mm Hg Pressure	Minutes Proof Time	Specific Loaf Volume
Salt[b]	<0.01	<0.01	<0.01	>0.05
Absorption[c]	<0.01	<0.05	>0.05	<0.01
Mixing time[d]	>0.05	>0.05	<0.05	<0.05
Salt × absorption	<0.05	>0.05	<0.01	<0.05

[a] Mixing time × absorption all not significant, except specific loaf volume, <0.01. Salt × MT not significant.
[b] Percentage of salt: 1, 1.5, and 2.
[c] Percentage of absorption: 57.5, 59, and 60.5.
[d] Minutes mixing time: 3.5, 4, and 4.5.

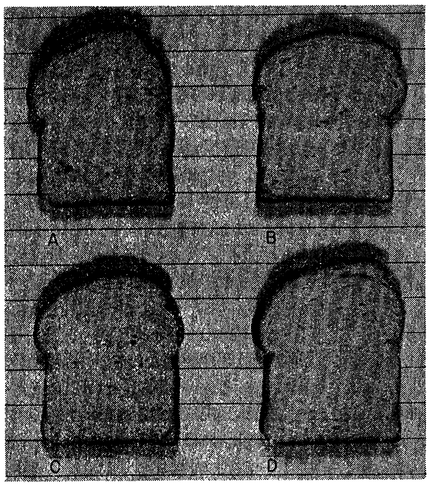

Fig. 6. Effect of salt level on the appearances of center cut bread slices for hard red spring flour. A = 0%; B = 1%; C = 1.5%; and D = 2% salt.

Grain and bread scores were unaffected for the main effects shown in Table XI. Dough handling was optimal at 59% absorption. As with HRS flours, reducing the salt from 2 to 1% produced a poorer sheeting and slightly stickier dough out of the mixer at optimum mix times: 3.5 min for 1% salt doughs, 4 min for 1.5% salt doughs, and 4.5 min for 2% salt doughs.

Grain, symmetry, and height of the center slices of breads with no salt or 1, 1.5, and 2% salt were similar (Fig. 6). Specific volumes of the cut loaves are much the same, ranging from 5.68 to 5.80 cc/g. Reducing the yeast level did not favorably affect the handling of doughs, as with HRS flour doughs, or affect the specific volume and appearance of the breads. Compressions of stored 1 and 2% salt breads were similar, except the three-day-old 1% salt breads were significantly firmer. Both salt breads were significantly softer than the salt-free stored breads. Shocking of proofed doughs also caused no significant change of volume in any of the breads.

Salt levels of 1–2% did not significantly affect the flavor and texture ratings of HRW flour breads containing 7.5% sugar that were evaluated when they were one and three days old (Table XII). Analyses were made in duplicate. Flavor ratings of breads made from this flour were lower

Table XII. Effect of Salt Levels on the Flavor and Texture Hedonic Scores of Hard Red Winter Flour Breads[a]

Percentage of Salt	1-Day-Old Flavor	1-Day-Old Texture	3-Day-Old Flavor	3-Day-Old Texture
1	5.92	6.52	5.52	6.13
1.5	6.04	6.59	5.66	6.24
2	5.83	6.52	5.15	6.10

[a] Column differences all not significant.

than those given one-day-old salt breads with HRS flour (Table IX), but texture scores were similar.

Using a second lot of HRW flour containing 11.6% protein, flavor ratings of 6.30 for one-day-old 2% salt bread and 6.65 for 1% salt bread were obtained. Ratings of 5.67 and 5.84, respectively, for three-day-old bread were obtained. Some staleness occurred in three-day-old HRW flour breads of both lots, which may have contributed to their lowered hedonic ratings. The flavor ratings of 1% salt breads made from HRW flours were as high or higher than those of the 2% salt breads. This may be due to the gradual acceptance of the panel to bread of lower salt content (the studies with HRW flour were the last to be made). This view is supported by a previous report (13).

CONCLUSION

Studies with both HRS flour containing 13.8 and 12 protein and HRW flour containing 10.8% and 11.7% protein showed that reducing salt content from the normal 2% to 1% decreased mixing times, mixing time to clean-up, and proof times of doughs. Yeast activity also increased and optimum dough development was slightly impaired. Optimum bake absorption, the effect of shocking of fully proofed doughs on bread volume, compressions, and total scores of breads were not significantly affected. Lowering the yeast level in 1% salt doughs by 36–38% increased proof times of these doughs to equal those of 2% salt doughs and produced very acceptable breads. Lowering the yeast level using HRS flour produced a better handling dough.

Compared to salt-free doughs, 1 and 2% salt HRS flour doughs handled much better; the flavor of their breads was highly rated by the panel. However, comparison of the flavor of 1, 1.5, and 2% salt breads at 4.5, 6, or 7.5% sugar showed that one-day-old 1% salt breads were rated significantly lower than the other two. These differences in score were relatively small; the averages rated above "like slightly" on the nine-point hedonic score. Additional data from a larger panel could help prove that these small differences are real. Salt did not significantly affect the flavor ratings of these three-day-old breads. In contrast, one-day-old HRW flour breads with 1, 1.5, and 2% salt were not significantly different. Using 1% salt in place of 2% salt shortened processing times of doughs and bread from both types of flour and produced acceptable breads with only slight impairment of initial dough handling and possible loss of flavor but not objective or subjective texture quality. 1.5% salt only very slightly impaired initial dough handling and its breads were fully as acceptable as those with 2% salt.

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